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# Validating a Sham Condition for Use in High Definition Transcranial Direct Current Stimulation

Emily O. Garnett*, Dirk-Bart den Ouden

*University of South Carolina, Department of Communication Sciences and Disorders, 915 Greene Street Suite 202, Columbia, SC 29209, USA*

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ABSTRACT

High Definition Transcranial Direct Current Stimulation (HD-tDCS) offers improved focality for targeting specific brain areas to modulate neural excitability, compared to conventional tDCS. HD-tDCS is associated with increased scalp sensation during stimulation, potentially rendering conventional tDCS sham methods ineffective due to lack of blinding. Here we report validation data on a novel method for modeling the sham condition in HD-tDCS studies. Thirty-one participants completed sensation ratings during 20 min of continuous active versus sham stimulation. Over half of the participants reported feeling the stimulation for the duration of the experiment. There were no statistically significant differences in sensation ratings between sham and active stimulation. Further, participants were unable to guess above chance level when they received sham stimulation.

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## Introduction and purpose

High Definition Transcranial Direct Current Stimulation (HD-tDCS) is a safe, non-invasive method of brain stimulation that offers greater target focality than conventional sponge tDCS [1,2]. Novel optimized localization algorithms based on extensive computerized modeling form a significant improvement, providing information about particular electrode configurations required to stimulate a target area [3,4]. Compared to conventional tDCS, however, HD-tDCS is associated with greater scalp sensation, which affects the development and application of sham (placebo) conditions. The sensation of conventional tDCS typically subsides quickly, so many researchers simply ramp down stimulation after 30 s in order to create an effective sham [5]. In HD-tDCS, however, participants may feel the sensation throughout the duration of the stimulation (up to 20 min), so this conventional method of sham stimulation may be inadequate [6].

This technical report provides validation data for a method of HD-tDCS sham modeling, based on continuous stimulation. The data presented are from 31 participants in a study investigating the effects of neurostimulation on phoneme monitoring in healthy speakers ($n = 20$) and people who stutter ([PWS] $n = 11$). Detailed experimental results are beyond the scope of this paper, but a brief report of the methods and results is reported below.

## Stimulation location and experimental protocol

The target location for stimulation was the left posterior superior temporal gyrus (pSTG), based on fMRI data that associate performing a speech monitoring task with a cluster of activation peaking in the left pSTG [7].

Electrode montages were configured using dedicated software (HD-Targets™ and HD-Explore™; [1]), maximizing stimulation of the target area, as shown in Fig. 1. Participants received stimulation in each of three experimental conditions – left posterior field orientation (LPFO), right anterior field orientation (RAFO), and sham – in counterbalanced order across participants. The LFPO and RAFO were selected as analogs of the conventional anodal/cathodal distinction, as they result in opposite polarities. Stimulation was administered with a total current strength of 2 mA for 20 min in the LPFO and RAFO conditions. A sham condition was modeled separately, also with total current of 2 mA, but split between two adjacent pairs of electrodes, in order to closely approximate the stimulation parameters set in LPFO and RAFO (see Sham Modeling section).

At least 24 h separated the conditions in order to minimize potential carryover effects. In all three sessions, the same materials

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* Corresponding author. Tel.: +1 803 777 9241.
*E-mail address:* garnette@email.sc.edu (E.O. Garnett).

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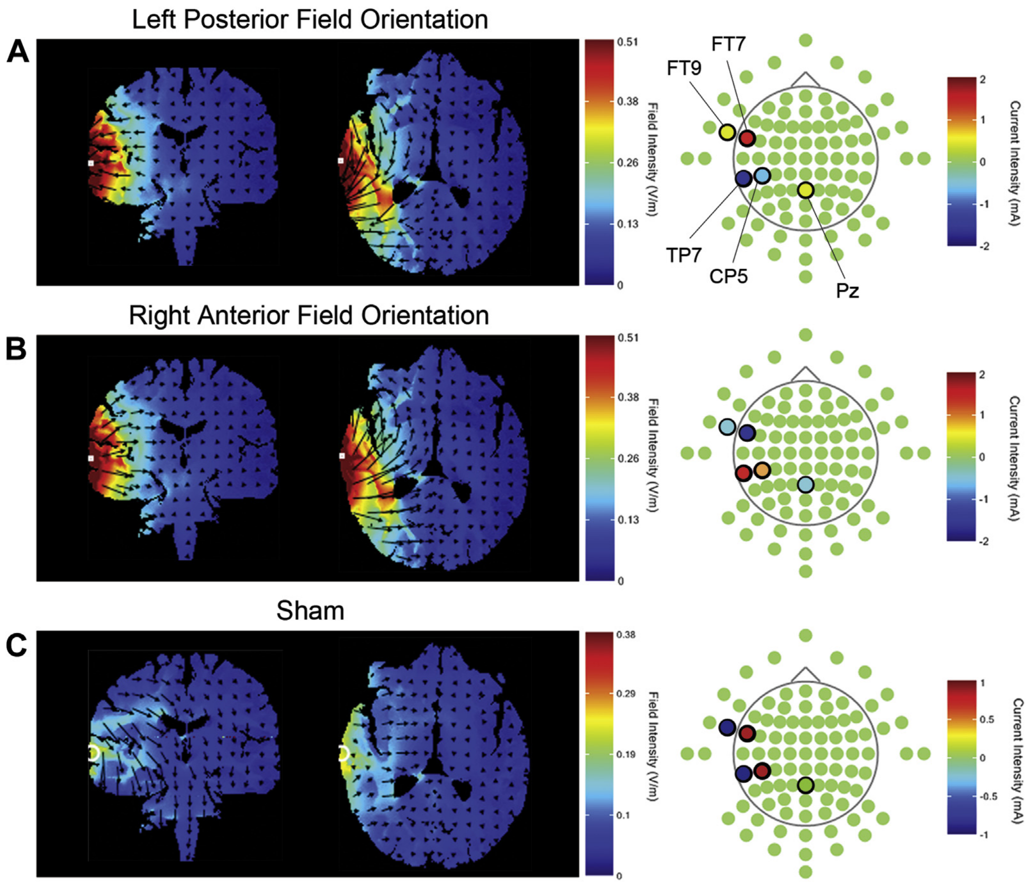


**Figure 1.** Field and current intensities as well as electrode montages for Left Posterior Field Orientation (Panel A), Right Anterior Field Orientation (Panel B), and Sham (Panel C) as modeled for target area left posterior superior temporal gyrus (#442 in HD-TargetsTM) on an adult male head. Note differences in scales between Panels A/B and Panel C.

and set-up protocol was used. Participants were seated comfortably in a chair in a quiet room. First, head size was measured to determine placement of the correctly-sized cap containing plastic electrode inserts. Following placement of the cap, hair was gently moved aside to reveal the scalp under each electrode insert through adjacent holes in the cap. A small amount of conducting gel was placed in each electrode insert, followed by AgCl sintered electrodes, additional gel to cover the electrodes, and finally the insert caps. Impedances were measured and when necessary, we cleared the scalp again and/or added additional gel until impedances were satisfactory. Immediately following each stimulation session, participants completed a short behavioral phoneme detection task.

## Sham modeling

In pilot work, we asked participants to rate both unpleasantness and pain, separately, on scales from 1 (none) to 10 (unbearable) at three time points over the course of a 20 min HD-tDCS session: (1) 30 s after ramp up, (2) 10 min (halfway), and (3) 30 s prior to ramp down. Results suggested that although both pain and unpleasantness decreased over time, many participants did experience pain and/or unpleasantness at least 10 min into the stimulation, and some for the full 20-min session. Therefore a simple ramping up and down of the electrical current, providing 30 s of stimulation, as in conventional tDCS, likely does not result in participant blinding.

One potential solution to this problem is to model a sham condition separately, configuring the current such that it bypasses the cortical surface, primarily traversing across the scalp instead [6]. Richardson et al. [6] reported no significant differences in scalp sensation ratings when comparing this type of sham, using a single electrode, to an experimental condition, during 5 min of stimulation. Similarly, we chose to model our sham condition using the same electrode configurations as our experimental set-up, yet with different current distribution. By using the same configurations, participants are unable to identify the sham condition using cues related to placement of electrodes in different locations in one session versus another. This set-up is also preferable to using continuous stimulation of an area not thought to be functional to the task (e.g., occipital lobe), as this might still allow participants to detect differences in set-up, especially those with prior knowledge of the domain under investigation (e.g., language or visual processing).

Figure 1 shows the electrode arrays in two experimental conditions (panels A and B) as well as sham (panel C). We first used HD-Targets™ (panels A and B) to determine an electrode configuration that was optimal for stimulation of our target region (left pSTG). The resulting 5 electrode locations and their corresponding current strengths and polarities are listed in Table 1. To model the sham

**Table 1**
Electrode locations and current strengths (in mA) in each of the 3 stimulation conditions (sham, left posterior field orientation [LPFO], and right anterior field orientation [RAFO]).

| | FT9 | TP7 | CP5 | Pz | FT7 |
|---|---|---|---|---|---|
| Sham | 1 | 1 | −1 | 0 | −1 |
| LPFO | 0.32 | −1.21 | −0.79 | 0.31 | 1.37 |
| RAFO | −0.32 | 1.21 | 0.79 | −0.31 | −1.37 |

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